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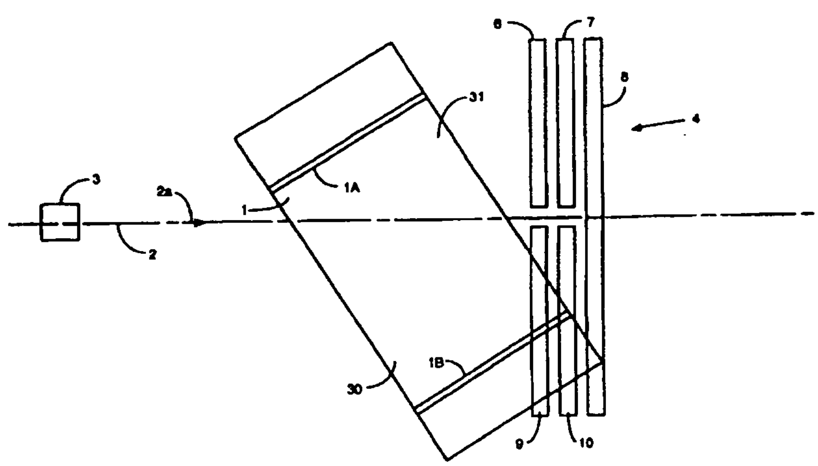

(57) Abstract

Apparatus for monitoring a document (11) to determine the presence of an electrically conductive element (1a, 1b) on or in the document (1) as the document is fed along a path (2). The apparatus includes at least two detection systems (40, 41) laterally spaced apart with respect to the direction of movement of the document along the path. The detection systems include antennae (6, 7, 8, 9, 10) for generating and detecting signals which are modified in the presence of an electrically conductive element (1a, 1b). A control system (20) is connected to the detection systems (40, 41) for monitoring signals from the detection system. Furthermore, a document detector (42, 43) for each detection system (40, 41) is positioned upstream of and on the same side of the centre line of the document feed path (6) of the respective detection system (40, 41). Each document detector (43) is connected to the control system (20), with the control system (20) being responsive to signals from the document detectors (42, 43) to monitor the corresponding detection system (40, 41) in a predetermined manner. This takes account of a skew fed document (1) to indicate the presence of an electrically conductive element (1a, 1b) if the monitored signals satisfy predetermined conditions.

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APPARATUS FOR MONITORING A DOCUMENT

BACKGROUND TO THE INVENTION

The invention relates to apparatus for monitoring a document to determine the presence of an electrically conductive element. Examples of documents which incorporate such elements include banknotes and other documents of value which include elements such as security threads.

DESCRIPTION OF THE PRIOR ART

An example of a known security thread detector is described in WO-A-94/22114. In this example, a document to be verified is passed over a detector defined by a pair of laterally spaced sensor plates and a number of guard plates. An electrical voltage is applied to the sensor plates and the system measures the disturbance of an electrical charge on the plates due to changes in capacitance caused by the presence of a metallic thread.

In another form of apparatus which is used by the applicants and which will be described in more detail below, a detector defined by a number of transmit antennae and a receive antenna is provided, the receive antenna being positioned downstream of the transmit antennae. As a metal thread passes over the transmit and receive antennae, it is capacitively coupled to them and conducts rf signals between them enabling the thread to be detected. In this known apparatus, a document detector is provided upstream of the thread detector to detect the arrival of the leading edge of a document, the document detector being positioned generally on the centre line of the document feed path. This then enables the processing electronics connected to the detector to compute when the document is expected to arrive at the thread detector and thus when it can be expected that a thread should be detected.

Although this known system works in general satisfactorily, the performance can be degraded when documents are fed in a skewed manner to the thread detector. In particular, the apparatus cannot determine

accurately from the document detector when a thread should arrive at the thread detector leading to the risk of erroneous outputs.

SUMMARY OF THE INVENTION

In accordance with the present invention, apparatus for monitoring a document to determine the presence of an electrically conductive element on or in the document as the document is fed along a path comprises at least two detection systems laterally spaced apart with respect to the direction of movement of the document along the path, the detection systems having means for generating and detecting signals which are modified in the presence of an electrically conductive element; a control system connected to the detection systems for monitoring signals from the detection signals; and a document detector for each detection system, positioned upstream of and on the same side of the centre line of the document feed path of the respective detection system and connected to the control system, the control system being responsive to signals from the document detectors to monitor the corresponding detection system in a predetermined manner which takes account of a skew fed document and to indicate the presence of an electrically conductive element if the monitored signals satisfy predetermined conditions.

In this invention, we provide additional document detectors associated with each detection system and also enable the control system to monitor the performance of the document detectors independently thus overcoming the problems of skew fed documents.

Typically, the document detectors will be positioned much closer to the respective detection system than the conventional centrally placed document detector enabling the control system accurately to determine when the leading edge of a document reaches the detection system. Effectively, the detection of the leading edge of a note by a document detector results in the generation of a synchronise command for that detector, the control system

then determines from a knowledge of the feed rate of the document and the time of the synchronise command, when it can be expected that the leading edge will arrive at the detection system. From this it can determine from when the control system will monitor signals from the detection system.

If the document detectors are positioned closer to the detection systems than the expected inter-document gap then this even eliminates the need for the control system to time the passage of the leading edge to the detection system while a preceding document is being processed.

In a simple example, the control system responds to signals from the document detectors only to monitor signals from the detection systems. However, in the preferred arrangement, the control system also controls operation of the detection systems, for example by controlling connection of (preferably rf) energy to the detection systems.

Conveniently, the control system includes a common signal source and first switching means for selectively connecting the signal source to the detection systems. Typically, the first switching means enables the signal source to be coupled in a multiplexed manner to the detection systems. In this way, the control system is able to operate the detection systems independently or in groups substantially simultaneously.

Although the control system could provide a comparator for each detection system, preferably the control system provides a common comparator to which signals from each detection system are fed via a second switch connected to each of the detection systems. In this way, the signals from the detection systems are fed in a multiplexed manner to the comparator.

In one example, a single detection system is positioned on either side of the centre line of the document feed path. In preferred examples, however, one or both of these detection systems are defined by at least two

subsidiary detection systems which can be independently monitored by the control system. In this case, where a common signal source is provided, the first switch can be operated to pass signals to selected subsidiary detection systems independently of the other detection systems.

Typically, each detection system or subsidiary detection system will comprise a transmit antenna and a receive antenna with the receive antenna usually positioned downstream of the transmit antenna. In a more preferred example, each detection system or subsidiary detection system includes more than one transmit antenna which can be used to take account of different minimum lengths of electrically conductive elements.

Conveniently, each receive antenna forms part of a common receive antenna. This simplifies construction of the apparatus.

Typically, the signals will be rf signals.

As mentioned above, the invention is applicable to the detection of many types of electrically conductive elements on documents but is particularly suitable for use in monitoring documents carrying elongate electrically conductive elements such as metallic threads. Such elements will be fed in a direction such that they are not parallel with the antennae.

BRIEF DESCRIPTION OF DRAWINGS

Some examples of banknote thread detectors according to the invention will now be described and contrasted with a known example with reference to the accompanying drawings, in which:-

Figure 1 is a schematic plan of known banknote magnetic thread detecting apparatus showing the feeding of a skewed note;

Figure 2 is a block circuit diagram of the processing electronics used with the Figure 1 example;

Figure 3 is a view similar to Figure 1 but showing an example of apparatus according to the invention;

Figure 4 is a block diagram of the processing electronics for use with the Figure 3 example;

Figure 5 illustrates a modified form of the apparatus shown in Figure 4; and,

Figure 6 illustrates how skew is handled in the Figure 5 example.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In order that the invention can be understood, we will describe firstly a known banknote metal thread detector which is implemented by the applicants. This is shown in Figures 1 and 2. As can be seen in Figure 1, a banknote 1 is fed along a feed path 2 in the direction indicated by the arrow 2a by a feed system (not shown) which may be a belt, roller or vacuum feed system of conventional type. A central track sensor 3 is positioned upstream of a detection system 4 positioned in alignment with the feed path 2. The detection system 4 comprises two pairs of aligned transmit antenna plates 6,9;7,10 positioned upstream of a receive antenna plate 8.

The antennae 6-10 are embedded in a flat surface in parallel with the note feed path 2 beneath a thin insulated covering. There is an earth screen below and around the outside edge of the antennae, and between the receive antenna 8 and the transmit antennae 7,10 which is closest to the receive antenna in order to minimise stray capacitive coupling between them. The earth screen is not shown in the drawings.

The receive antenna 8 is positioned further forward in the transport direction so that the note leading edge passes over the transmit antennae 6,7,9,10 before it reaches the receive antenna 8.

Two pairs of transmit antennae 6,9 and 7,10 are provided to allow for two different minimum metal thread lengths to be selected. The minimum metal thread length is determined by the physical distance between the selected transmit antennae and the receive antennae 8. However, this could be expanded so that there are more than two

selectable transmit antennae placed at different distances from the receive antenna 8. The non-selected transmit antennae are also grounded to prevent stray capacitive coupling of the signal between them, the metal thread, and the receive antenna from influencing the signal.

The processing electronics connected to the detector system 4 is shown in Figure 2. A crystal oscillator 11 running at an rf frequency is provided which is connected to a gating circuit 12 which can switch the output onto a selected one of the aligned transmit antennae 7,10 or 6,9 which extend either side of the feed path to cover the full width of the note. As can be seen in the drawings, there is a small gap between the aligned antennae which can be narrower than a metal thread switch to avoid having a null point at the centre.

The transmit antennae 6,7,9,10 are connected individually to the gating circuit 12 via respective amplifiers 13.

The receive antenna 8 is connected via a ceramic filter 14 onto the input of a high gain rf/if amplifier module 15 which provides a signal strength output 16 and has a feedback gain control 17 from the output which adjusts the if amplifier gain and helps to compensate for variations in the residual signal level due to stray capacitive coupling from dirt build-up or condensation. The if amplifier gain control 17 has a long time constant so that it does not affect the signal produced by the metal thread.

The main intelligence in the system is provided by a process controller 18 in the form of a microprocessor which can select different modes of detection, controls the overall processing, interprets the metal thread detector signal from the detection system 4 and communicates whether or not the note appears to have a genuine metal thread to a main controller 20 via an external interface 19.

The signal strength output is amplified to obtain a measurable voltage level and then fed via a glitch filter

21 to the inverting input of a comparator 22. This forms part of a voltage comparator circuit, the non-inverting input of the comparator 22 being fed from a comparator threshold selection circuit 23 controlled by the process controller 18 with a predetermined threshold level. The output from the comparator 22 changes the logic state on the input to the process controller 18 when the threshold is exceeded, indicating the presence of a metal thread.

The operation of the apparatus shown in Figures 1 and 2 is as follows.

The process controller 18 first receives a "run command" from the main controller 20 after which it is ready to receive synchronise commands and start the metal thread detection process.

The process controller 18 receives a synchronise command from the main controller 20 (via the external interface 19) which indicates the arrival of a note leading edge at the track sensor 3 which is positioned in advance of the metal thread detector 4 and central to the note path.

The process controller 18 has access to timing pulses on the external interface 19 which relate to the movement of the note transport, and uses these to determine when the note leading edge central to the transport arrives at the metal thread detector 4 at which point it starts the metal thread detection process.

The main controller 20 notifies the process controller 18 of the expected note separation which enables the process controller 18 to determine which pair of transmit antennae 6,9 or 7,10 should be activated. Prior to the arrival of the note 1 at the detector 4, the process controller 18 activates the selected pair of transmit antennae by suitably controlling the gating circuit 12 to connect the oscillator 11 with the selected pair of transmit antennae.

As the banknote 1 is being transported through the system the start of the metal thread 1A or 1B (only one

thread per note) on the leading edge of the note arrives first at the selected transmit antennae and then reaches the receive antenna 8. From this point, a small area of the two antennae are covered by the metal thread until the metal thread on the note trailing edge reaches the transmit antennae.

The metal thread 1A,1B is capacitively coupled with the transmit antennae and receive antenna as it passes over the detector 4, and conducts the coupled rf signal between them, so that a proportion of the rf signal is received on the input of the high gain rf/if amplifier module, which produces a voltage level change on the signal strength output.

The process controller 18 has to be capable of receiving a synchronise command and timing the next note leading edge from the track sensor 3 while the metal thread detection process is being carried out on the current note. This is because the distance between the centrally positioned track sensor 3 and the metal thread detector 4 is greater than the inter-note gap (distance between the lead edges of consecutive notes).

The main controller 20 tracks the trailing edge of a note 1 through the transport and determines when it has arrived at the metal thread detector 4, at which point it commands the process controller 18 to send the status of the current note being detected for a metal thread presence indication. The process controller 18 then stops the detection process for the current note if it is still active and sends the status containing the presence or non-presence of a metal thread to the main controller 20.

The process controller 18 would already have stopped processing if either: a sufficient length of metal thread had been detected, the process had timed out with no metal thread detected, or it had determined that the metal thread was not genuine.

Once the metal thread detection process has been stopped and the process controller 18 has returned the

status to the main controller 20, it is ready to restart the process when the timing for the lead edge of the next note indicates it has arrived at the metal thread detector 4.

If the timing for the next note lead edge indicates that it has arrived at the metal thread detector before the process for the current note is stopped, the process controller 18 stops processing any more notes and reports an overrun condition in response to the next status read command from the main controller 20.

The metal thread detection process continues until there is an overrun or a "stop" command is received from the main controller 20.

The signal strength amplifier gain and the comparator threshold setting can be adjusted by the process controller 18, and the glitch filter 21 on the input to the comparator 22 can be switched on or off by the process controller 18.

Switching transmit antennae are used as opposed to switchable receive antennas, because the received rf signal level is a very much lower than the transmitted signal level, and switching at this low level would result in a high attenuation of the signal.

A metal thread having micro-breaks or discontinuities along the thread will produce variations in the detected signal level.

A section of metal thread which has no discontinuities and is longer than the selected minimum thread length (i.e. the distance between the transmit and receive antennas) will produce pulses on the output of the comparator 22. The duration of the pulses and the time between them are used to determine whether the metal thread is genuine.

The operation described above works well when notes are fed with their leading edge substantially orthogonal to the feed direction. Problems can arise, however, with skewed notes as shown in Figure 1.

The problem of note skew arises because the metal thread detector 4 receives the synchronise command and

times the note lead edge from the track sensor position to the metal thread detector position along the centre of the note path 2 in order to start the metal thread detection process.

If the metal thread is present on the left hand side (LHS) 30 of the note (as shown at 1B) which is skewed forward the metal thread detection process starts too late, and the leading portion of the metal thread is not processed by the metal thread detector 4.

Conversely, if the metal thread is on the right hand side (RHS) 31 of the note (as shown as 1A) which is skewed backward, the metal thread detection process starts before the note lead edge has arrived at the metal thread detector 4, with a risk that the process will have timed out before a sufficient length of the metal thread had reached and passed through the detector.

The effects of note skew get worse with:

a) increased note skew.
b) the greater the distance the metal thread is away from the centre of the note.
c) the greater the lateral offset of the note with respect to the centre of the note path.
d) the shorter the length of the metal thread (short edge dimension of the note).

The effective length of the metal thread (in the direction of the transportation of the note) is also reduced when the note is skewed, to the product of the actual note length times its skew angle.

There would be a problem running the metal thread detection process continuously because of the variation in inter-note gap, and the possibility of leading and trailing edges of two notes which are skewed in the same direction being in-line across the detector.

In order to overcome these problems, we replace the single detector 4 shown in Figure 1 with a pair of detectors, a LHS detector 40 and a RHS detector 41 positioned on the left hand side and right hand side

respectively of the feed path 2. In addition, we provide, in place of the track sensor 3, a respective LHS track sensor 42 and RHS track sensor 43 beneath the note path and in alignment with the respective detectors 40,41. Preferably, the sensors 42,43 are centred on the respective detectors 40,41 with respect to the feed direction.

This significantly improves the performance of the system with skewed notes by allowing the LHS and RHS processes to be synchronised separately in conjunction with the arrival of the leading edge of the note at each of the track sensors 42,43. It should also be noted that these track sensors 42,43 are positioned much closer to the detectors 40,41 than the central track sensor 3. Positioning the track sensors 42,43 closer to the metal thread detectors 40,41 than the inter-note gap (physical constraints do not allow close proximity) eliminates the need for the process controller 18 to time a note lead edge to the metal thread detector position while the preceding note metal thread is being processed.

The RHS and LHS track sensors 43,42 are connected to the main controller 20 as shown in Figure 4. It should be noted that all components in Figure 4 which correspond to components shown in Figure 2 have been given the same reference numbers and will have similar functions. The main difference between the systems shown in Figures 2 and 4 is in the presence of the LHS and RHS track sensors 42,43 and in the ability of the process controller 18 to select the transmit antennae 6,7,9,10 individually and independently.

In operation, the main controller 20 generates an appropriate "synchronise" command when the leading edge of a note is sensed by either the RHS or LHS track sensor 43,42 which is fed to the process controller 18. These "synchronise" commands enable the process controller 18 to time the passage of the leading edge of the note to the corresponding detector 41,40 so as to start and run the

metal thread detection process independently for the LHS and RHS of the transport.

Having independent metal thread detectors 40,41 on the LHS and RHS of the transport path might require two rf amplifier circuits and comparators. This would almost double the cost of the electronics components used and there would be problems of cross coupling between the two detectors.

Instead, the process controller 18 provides separate (or multiple) LHS and RHS processes by multiplexing the rf oscillator output between the LHS and RHS transmit antennae 6,7;9,10 and monitoring the comparator output as each side is being driven to provide a separate LHS and RHS metal thread status when it receives a read command from the main controller 20.

An additional control signal from the process controller 18 is fed to the gating circuit 12 for multiplex switching the rf oscillator output onto either the LHS or RHS transmit antenna corresponding to the selected minimum thread length (ROW1 or ROW2), while at the same time grounding the transmit antenna on the opposite side. This may result in "simultaneous" operation of the detectors for a certain period and individual operation for other periods.

The maximum multiplexed scan rate will be limited by the response time of the amplifier and comparator circuit which needs to be faster than is used with the current design.

Because the metal thread position will vary with respect to the centre of the note with different currencies and denominations, the metal thread position may be inboard or outboard of the LHS or RHS track sensors 40,41. For this reason, the position at which the process controller starts the LHS and RHS metal thread detector process will need to be optimised, but the performance with skewed notes will still be a significant improvement than with the current method.

The performance with skewed notes could be improved still further by splitting the transmit antennae on the LHS and RHS into two or more separate elements which are driven independently by expanding the multiplex switching of the rf oscillator output, using additional control signals from the process controller 18 to the gating circuit 12. Figure 5 shows an example using four elements for each transmit ROW which consist of transmit antennae positioned on the outboard LHS 6A,7A, inboard RHS 6B,7B, inboard RHS 9A,10A and outboard RHS 9B,10B. Each transmit antenna is connected via a respective amplifier 13, independently, to the gating circuit 12. The process controller 18 would control a separate process for each element, and ground the non-selected elements while the selected element was being measured on the receive antenna 8. On receiving a synchronise command for the LHS or RHS from the main controller 20, the process controller 18 would first check whether the synchronise command for the opposite side has been received to determine the skew direction. The processes for the inboard and outboard elements would be initiated either earlier or later than one another depending on the direction that the note is skewed. The inboard and outboard signals on a particular side would be combined to provide a single status result for that side.

In order to explain the manner in which skew is handled in this arrangement, Figure 6 illustrates the four transmit antennae 6A,6B,9A,9B and the track sensors 42,43. It will be seen that each track sensor 42,43 is positioned in alignment with the mid point between the respective pair of transmit antennae 6A,6B;9A,9B. Each sensor 42,43 is positioned a similar distance L from these mid points. Lines 100,101 indicate successive locations of the leading edge of a skewed note being fed towards the detectors 40,41. As can be seen, the leading edge will first arrive at the sensor 42 as shown by the line 100. If the instant at which the leading edge was detected by the sensor 42 was used to initiate a time delay following which signals were

transmitted by each antenna 6A,6B then the leading edge of the note would have already passed the antenna 6A but would not yet have reached the antenna 6B. In order to deal with this, the process controller 18 determines the amount of skew by noting the time interval between which the leading edge 100 is detected by the sensor 42 and the time at which the leading edge is detected by the sensor 43. From the knowledge of the distance between the two detectors, the feed speed of the note, and this time interval, the process controller 18 can then determine a skew distance SK shown in Figure 6. This can then be used to determine the time offset which must be applied before signals are caused to be transmitted from the antennae 6A,6B.

If the time to cover the distance L is denoted as T_L then the time interval from detecting the leading edge 100 at the sensor 42 to initiating transmission from the antenna 6A is $T_L-T_{SK/4}$. Similarly, the time before the antenna 6B commences transmission is $T_L+T_{SK/4}$.

CLAIMS

1. Apparatus for monitoring a document to determine the presence of an electrically conductive element on or in the document as the document is fed along a path, the apparatus comprising at least two detection systems laterally spaced apart with respect to the direction of movement of the document along the path, the detection systems having means for generating and detecting signals which are modified in the presence of an electrically conductive element; a control system connected to the detection systems for monitoring signals from the detection signals; and a document detector for each detection system, positioned upstream of and on the same side of the centre line of the document feed path of the respective detection system and connected to the control system, the control system being responsive to signals from the document detectors to monitor the corresponding detection system in a predetermined manner which takes account of a skew fed document and to indicate the presence of an electrically conductive element if the monitored signals satisfy predetermined conditions.

2. Apparatus according to claim 1, wherein the control system controls operation of the detection systems.

3. Apparatus according to claim 2, wherein the control system controls the connection of energy to the detection systems.

4. Apparatus according to claim 3, wherein the control system includes a common signal source; and first switching means for selectively connecting the signal source to the detection systems.

5. Apparatus according to claim 4, wherein the first switching means enables the signal source to be coupled in a multiplexed manner to the detection systems.

6. Apparatus according to any of the preceding claims, wherein the control system provides a common comparator to

which signals from each detection system are fed via a second switch connected to each of the detection systems.

7. Apparatus according to any of the preceding claims, wherein one or both of the detection systems is defined by at least two subsidiary detection systems which can be independently monitored by the control system.

8. Apparatus according to any of the preceding claims, wherein each detection system or subsidiary detection system comprises a transmit antenna and a receive antenna with the receive antenna positioned downstream of the transmit antenna.

9. Apparatus according to claim 8, wherein each receive antenna forms part of a common receive antenna.

10. Apparatus according to any of the preceding claims, wherein the signal generating means generates rf signals.

11. Banknote thread detection apparatus incorporating apparatus according to any of the preceding claims.

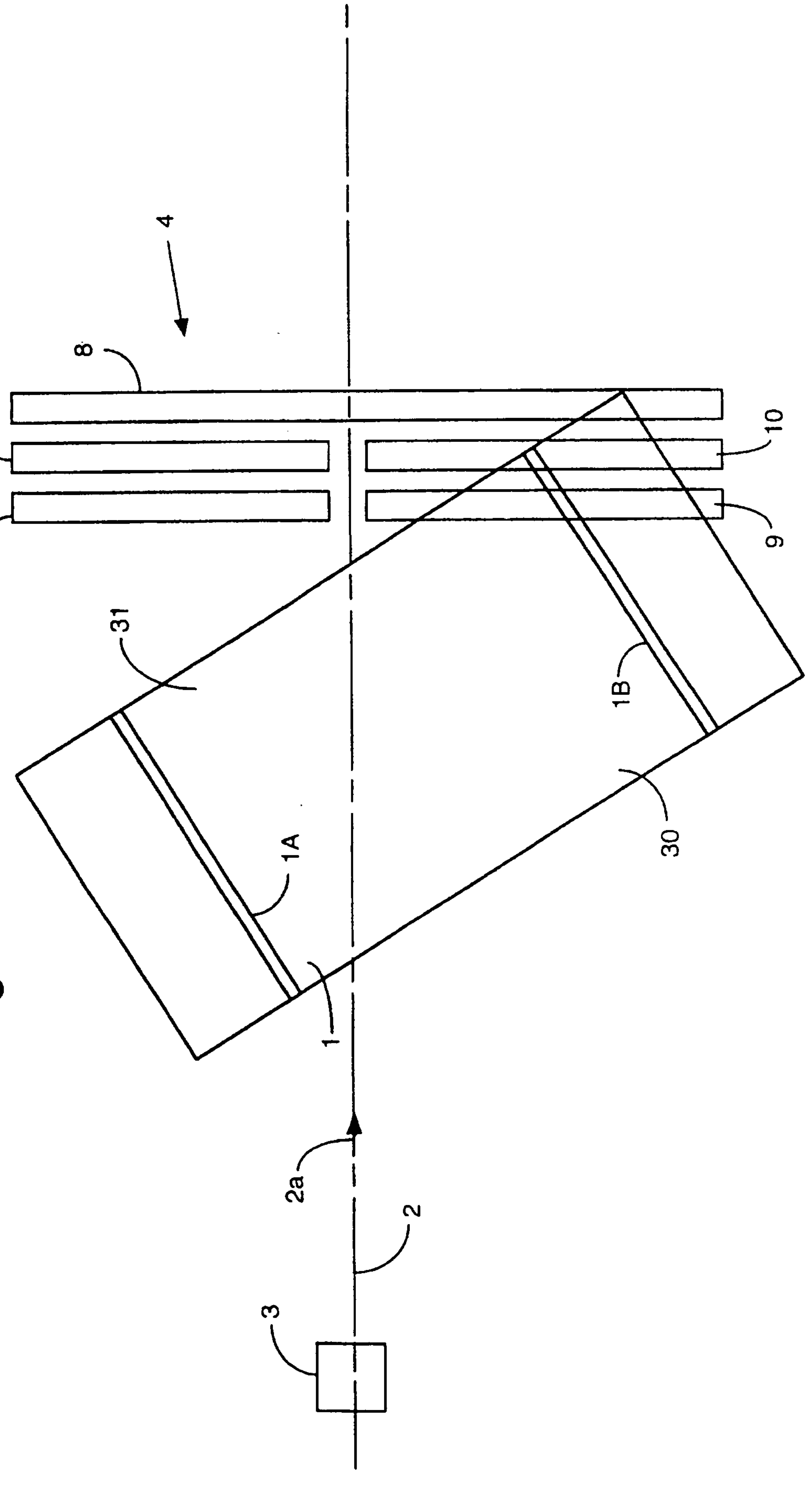
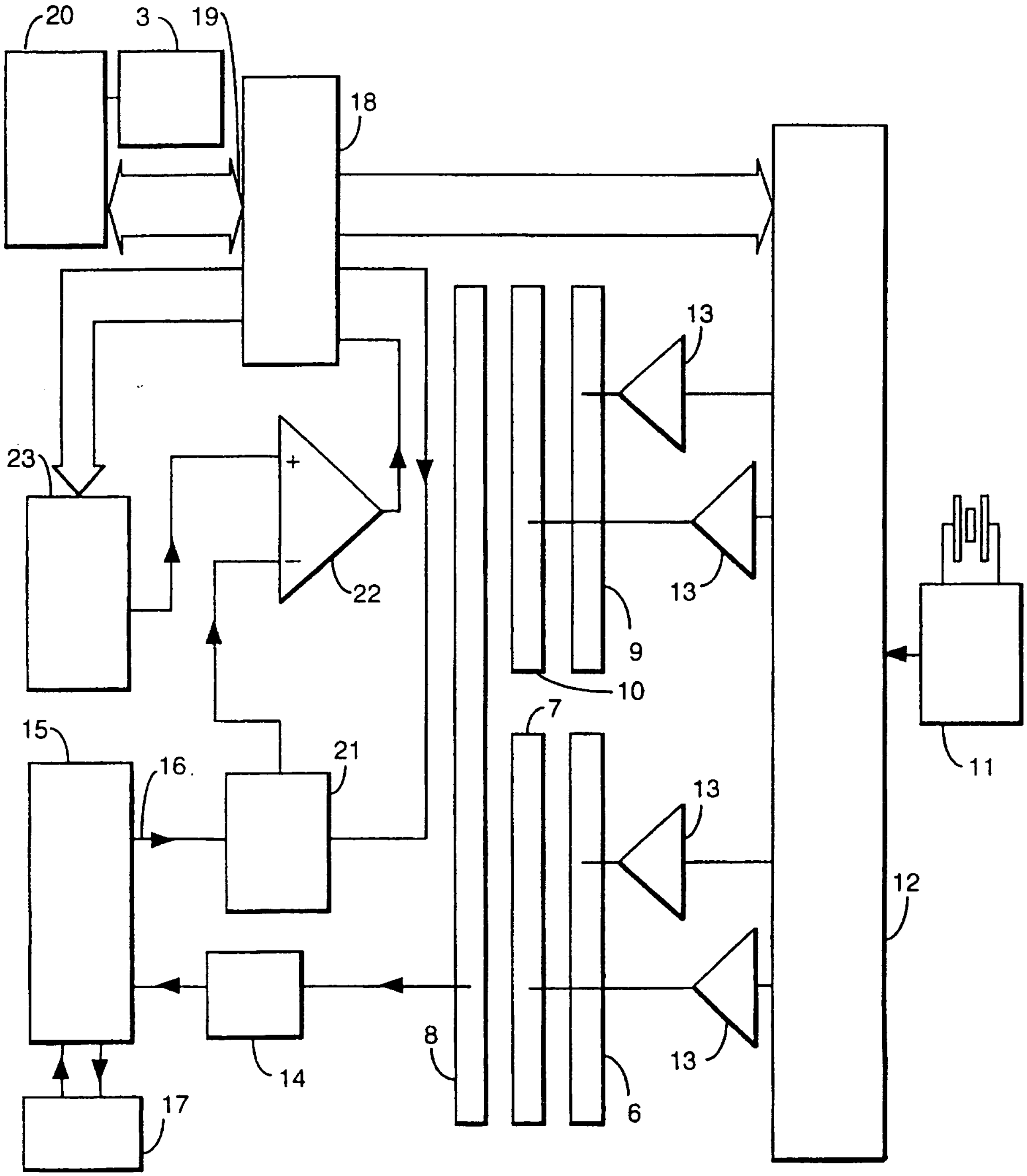


Fig.1. PRIOR ART

Fig.2.
PRIOR ART



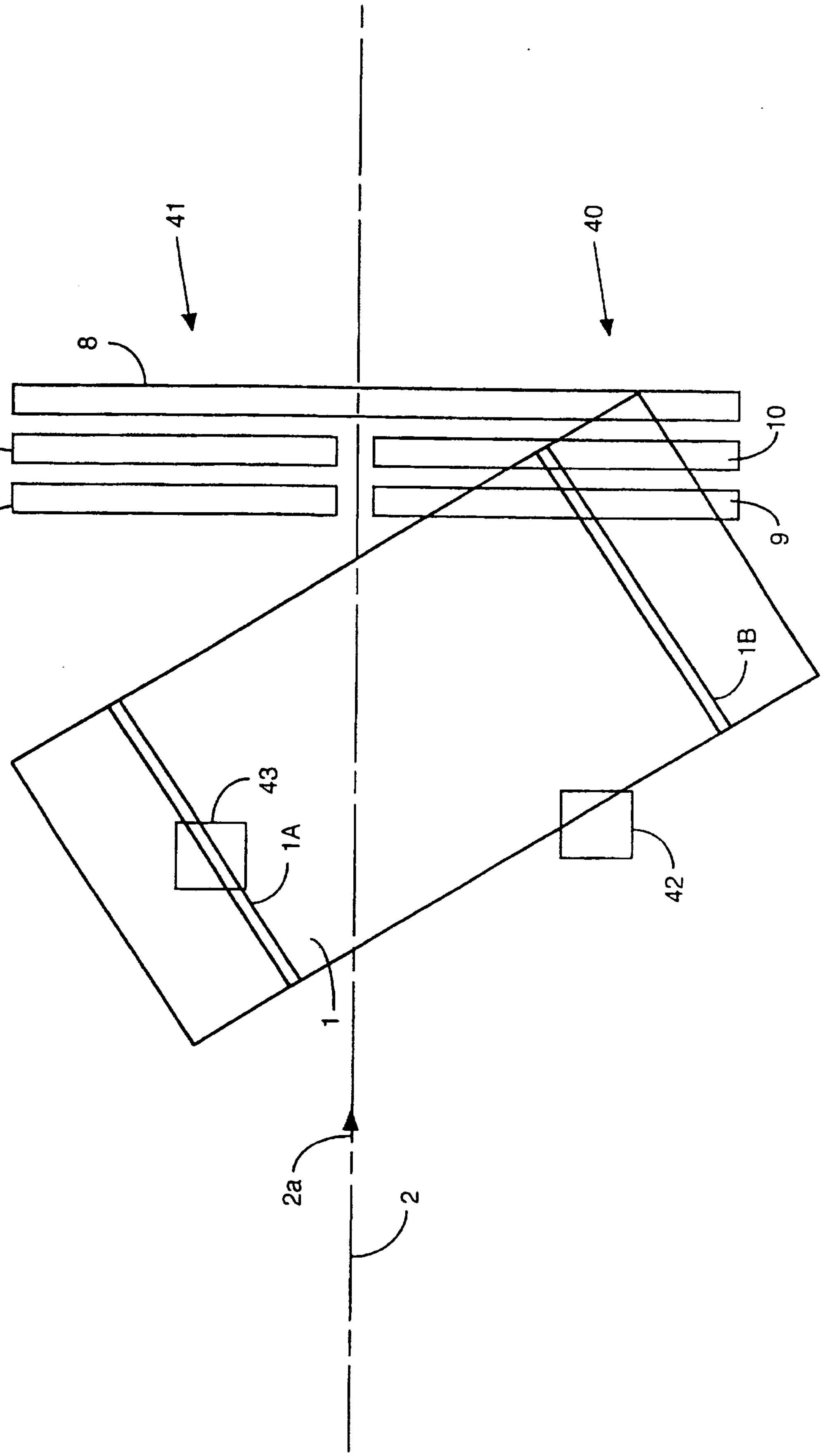


Fig.3.

Fig.4.

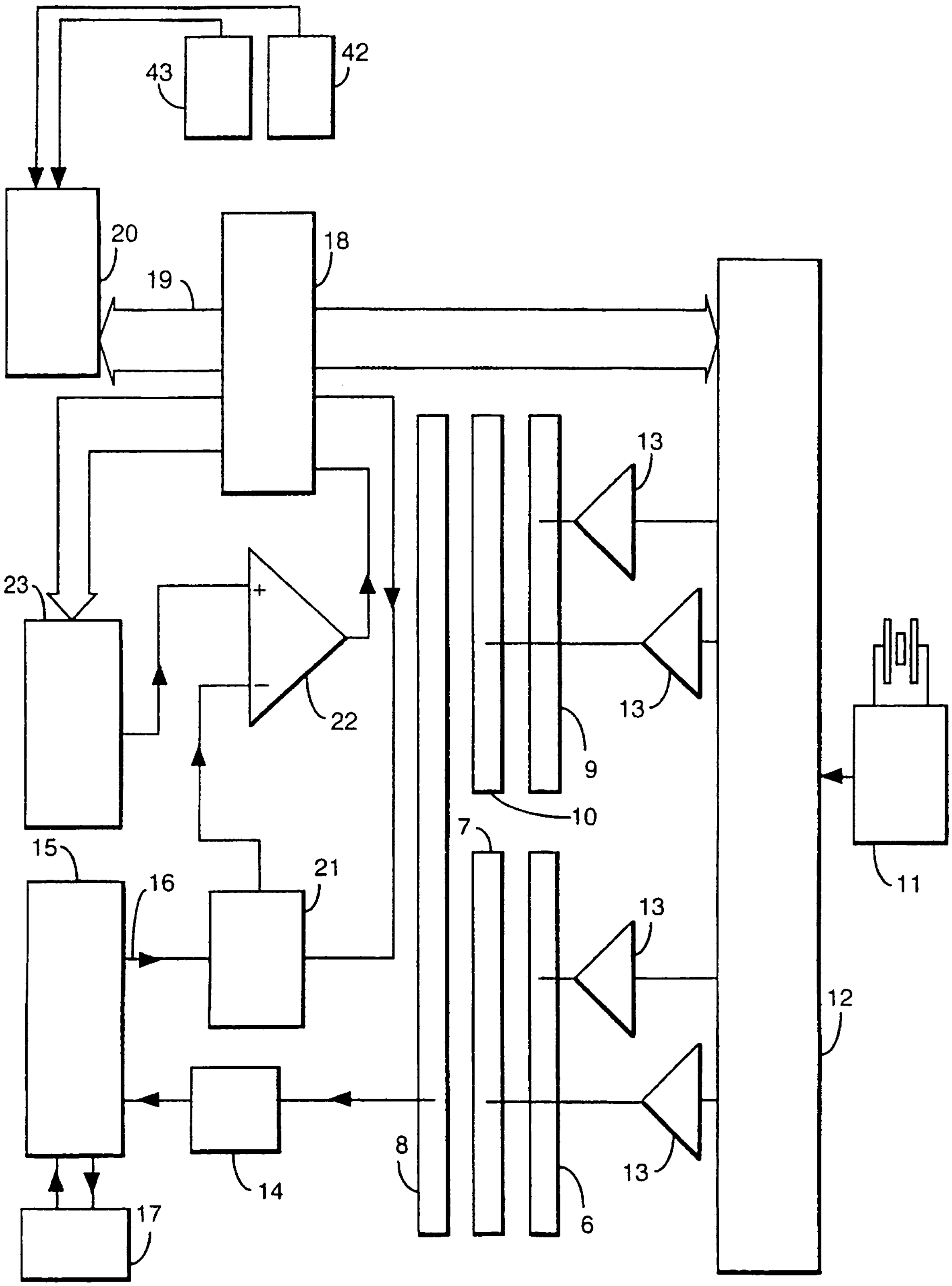


Fig.5.

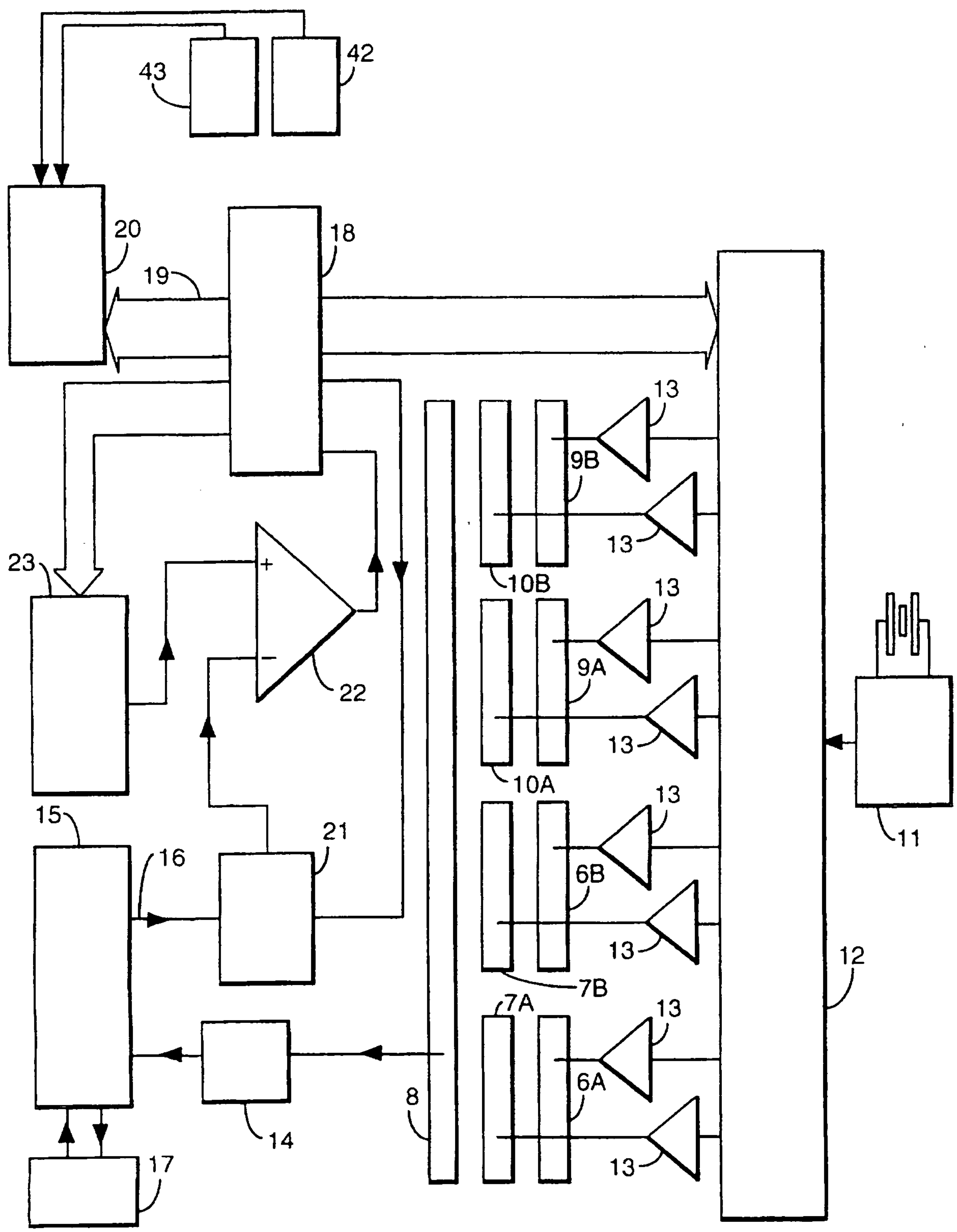
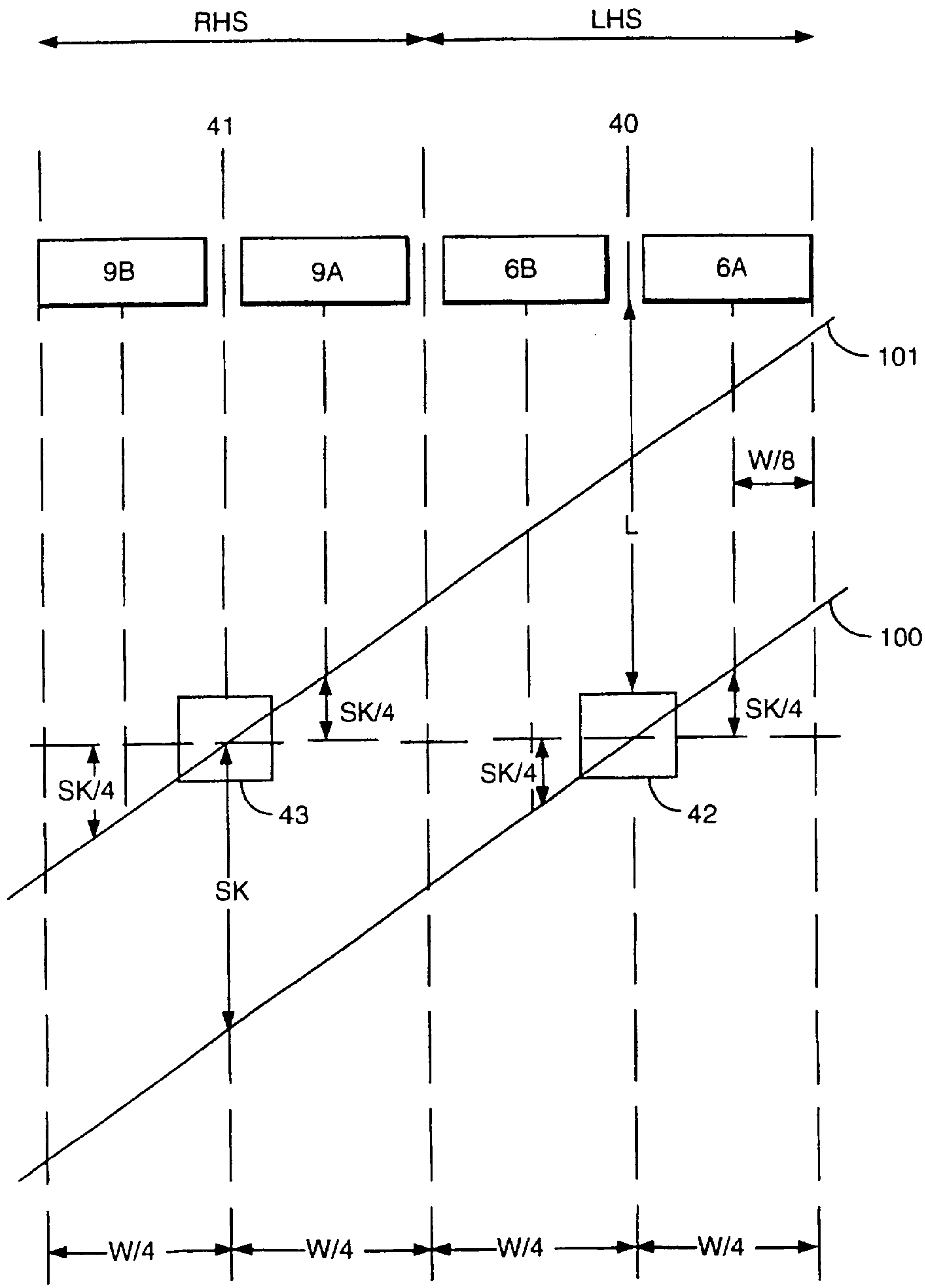


Fig.6.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INTERNATIONAL SEARCH REPORT

PC i/GB 97/01720

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G07D7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 44 05 860 A (WHD WARENHANDELS UND DIENSTLEI) 24 August 1995 see claim 1; figure 1 ---	1-12
A	EP 0 097 570 A (FLONIC SA) 4 January 1984 see claim 1; figure 1 ---	1-12
A	GB 2 129 126 A (DE LA RUE SYST) 10 May 1984 see claim 1; figures 1A-1H ---	1-12
A	EP 0 413 534 A (DE LA RUE SYST) 20 February 1991 see claim 1; figure 2 ---	1-12
A	US 5 363 949 A (MATSUBAYASHI KATSUYOSHI) 15 November 1994 see claim 1; figure 1 -----	1-12

☐ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 August 1997	28.08.97

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